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Environmental Impact of Inhaled Anesthetics: A Literature Review

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Abstract

Current research demonstrates that increasing air pollution causes significant increases in cardiac disease, pulmonary disease, and even death. The known consequences of increasing greenhouse gases parallel those of air pollution and include higher rates of cardiovascular disease, asthma, and infectious disease. This literature review aimed to identify, assimilate, and summarize the known impacts of volatile anesthetics on the Earth's environment. We present methods that are being used to reduce or eliminate these effects. We also aimed to summarize any known health effects on humans related to volatile anesthetic use and to review ways to reduce and eliminate these impacts. It is our hope that this review will provide evidence that leads to a change in current practice and future practice development that reduces the environmental impact and side effects related to volatile anesthetic use.

INTRODUCTION

Certified registered nurse anesthetists administer nearly 43 million anesthetics in the United States each year.[1] Many patients receive volatile anesthetics to induce and maintain a satisfactory depth of anesthesia. Volatile anesthetics are also greenhouse gases (GHGs).[2] Approximately 500,000 gallons of anesthetic GHGs are vented into the environment annually in the United States alone, an impact that translates to the GHG emissions of approximately 1 million vehicles annually.[2] GHGs serve to trap the sun's radiative energy in the Earth's atmosphere, contributing to global warming. These wasted anesthetic gases, which currently are not commonly recycled or reused, total nearly $1 billion in expenses bared by anesthesia providers and passed on to patients and 8% of total carbon dioxide (CO_2) emissions[3,4] annually in the United States alone.

Current research demonstrates that increasing air pollution causes significant increases in cardiac disease, pulmonary disease, and even death—including 16% of lung cancer, 11% of chronic obstructive pulmonary disease, and 20% of ischemic heart disease and stroke deaths.[5] An estimated 150,000 deaths per year (0.3% of all annual deaths) are said to be related to climate by the World Health Organization (WHO), and this number is expected to increase.[6] The climate-associated health risks identified by the WHO include food and water insecurity, increased transmission of infection, heat stress, more frequent and extreme weather events, threats to shelter and security, and population migration.[7]

Because of the medical necessity of volatile anesthetic gases, no prior regulations on emissions have been sought.[8] However, with the increased number of individuals undergoing surgery and anesthesia and the development of newer anesthetic agents, the environmental impacts of these anesthetics should be evaluated.

The purpose of this literature review was to identify, assimilate, and summarize the known impact of volatile anesthetics on the Earth's environment and the global population; to review ways to reduce and eliminate these impacts; and to provide evidence supporting the need for changes in current practice and future practice development that can reduce the environmental impact and side effects related to volatile anesthetic use.

HISTORY AND REVIEW OF THE LITERATURE

This systematic review of the literature began with a thorough search for articles relevant to this topic. The databases searched included EBSCOhost (EBSCO, Ipswich, MA), Google Scholar (Google Inc, Mountain View, CA), and Cochrane Review (The Cochrane Collaboration, London, United Kingdom). Search terms, used alone and in combination, included *environment, environmental, pollution, climate, global warming, anesthesia, anesthetics, inhalational anesthetics, volatile anesthetics, implications, health, management, waste, impact, life-cycle,* and *scavenging*. The literature search criteria were limited to pertinent English-language articles from the last 20 years. In total, 16 articles were located. Fourteen articles were included for review as 2 of the articles were not primary sources.

Anderson et al[2] provide an excellent chemical analysis of volatile anesthetics and describe their potential as both GHGs and ozone-destroying agents. According to these authors, all volatile anesthetics are GHGs, meaning that they have a significant atmospheric lifetime and possess infrared absorption bands that overlap the outgoing radiation from the Earth's lower atmosphere. GHGs trap the outgoing radiation and cause the Earth's temperature to rise. In addition to trapping radiation, some but not all GHGs also actively deplete the ozone. Ozone is an inorganic molecule that is most heavily concentrated in the stratosphere and that prevents ultraviolet radiation from reaching the Earth's surface.[9] The overall effect of GHGs and ozone-depleting gases is to increase the amount of the sun's radiation that enters and is trapped within the Earth's atmosphere, which is believed to cause climate change.

Isoflurane, compared with sevoflurane and desflurane, is the only volatile anesthetic capable of destroying stratospheric ozone, attributable to the catalyzation that its chlorine ion provides.[2] The global warming potential (GWP) of volatile anesthetics depends on the timeframe in which they are considered. Some agents may be strong GHGs and contribute strongly to ozone depletion, but their environmental half-life may be very short. Another agent may not be destructive to the ozone or as potent a GHG, but may stay in the atmosphere for hundreds of years. When assessing GWP, time frames of 20, 50, and 100 years are used. The 100-year time frame is the most widely used. Desflurane may be the most environmentally harmful, because it is used and released into the atmosphere in higher quantities. In addition, desflurane has a high GWP of over 100 years. Anderson et al[2] report that, ultimately, halogenated organic compounds are responsible for 10% to 15% of the radiation forces of climate change by GHGs.

Nitrogen oxides, including nitrous oxide (N_2O) and nitric oxide, are known ozone-depleting substances.[10] There has been great success in reducing ozone-depleting emissions of chlorofluorocarbons, chlorine, and bromine gases through the Montreal Protocol, an international treaty aimed at protecting the ozone layer by phasing out substances that cause ozone destruction. However, this has resulted in an increase in the contribution of N_2O to GWP; N_2O is now second only to methane. Although the primary anthropogenic source of N_2O emissions is fertilizer use, anesthesia providers should still be cognizant of the ozone-depleting capabilities of N_2O use.[10] The atmospheric lifetime of N_2O emissions, at 114 years, is much longer than that of the other inhaled anesthetics, which range from 1 to 14 years.[8] In addition, N_2O is usually used in greater volumes, at concentrations of 40% to 60%, in an anesthetic, thus increasing the impact over other anesthetics used in lower volumes at concentrations between 1% and 6%.[8]

In 2010 infrared spectrometry was used to estimate the GWP of inhaled anesthetics.[11] Looking at the 20-year GWP, desflurane and N_2O were reported to have significantly greater impacts on global warming than isoflurane or sevoflurane. Furthermore, N_2O was reported to contribute to the destruction of the ozone. These authors concluded that to minimize increases to global warming, providers should avoid using N_2O, use as low fresh gas flows (FGFs) as possible, and use either isoflurane or sevoflurane.[11]

Despite the controversy, the fact that desflurane and N_2O have significantly greater impacts than other anesthetics holds true. Using desflurane for 1 hour at 1 minimum alveolar concentration (the alveolar concentration of anesthetic needed to prevent motor response in 50% of subjects in response to surgical stimulation) equates to the GHG emissions of driving 200 to 400 miles in the average automobile.[8] The GHG emissions of sevoflurane and isoflurane are significantly lower, equaling the GHG emissions of driving 8 to 18 miles.[8]

Sherman et al[12] performed a cradle-to-grave analysis of volatile anesthetics, meaning they looked at the total environmental footprint of the volatile anesthetics. The data incorporated production, transport, use, and waste disposal as they relate to contribution to GHGs. Overall, the lifecycle phases of the volatile anesthetics contribute a relatively insignificant amount to their overall GHG emission compared to agent release into the atmosphere during use. The authors concluded that desflurane and N_2O contribute most as GHGs, while isoflurane and sevoflurane contribute much less, especially at low flows. They also reference several technologies in development with the potential to eliminate waste gases through capturing and recycling. These technologies include the Dynamic Gas Scavenging System (Anesthetic Gas Reclamation LLC, Nashville, TN) and the Deltasorb anesthetic collection service (Blue-Zone Technologies Ltd, Toronto, Canada).

Berry et al[13] described 4 operating rooms that had been equipped with reclaiming waste anesthetic gas (WAG) scavenging systems. Easy installation and 99% efficiency in eliminating WAG was reported. The authors concluded that recycled product may decrease cost and increase the availability of modern volatile anesthetics worldwide. While several authors have postulated that WAG could be reprocessed and reused using a scavenging system, this was the only trial of this technology that could be found in the literature.

Jänchen et al[14] performed trails of silica zeolite absorbers and found them useful in collecting desflurane from the waste gas outlet during anesthesia. These authors state that the use of charcoal absorbers is partially effective at filtering desflurane from WAG, therefore reducing the environmental waste of this gas. Zeolite consists of crystalline microporous aluminosilicates. Zeolite is much more effective in filtering and desorption of desflurane for collection. In the clinical trial, 62% to 86% of used desflurane could be collected with the use of zeolite filters.[14] This technology holds the potential to eliminate the environmental impact of desflurane. With purification, this recovered desflurane also holds significant economic savings potential.

Through the use of the GASman computer tool (Med Man Simulations, Chestnut Hill, MA), Feldman[15] was able to simulate the various phases of anesthesia, including induction, maintenance, and emergence, and the amount of volatile anesthetic used during each phase under certain FGFs and volatile anesthetics. He found that by reducing flows as safely as conditions allow, it may be possible to prevent the release of millions of liters of volatile anesthetics into the atmosphere over the course of a provider's lifetime. Key points included turning off flows while intubating, titrating flows to patient oxygen needs to reduce use of agents, keeping flows low during emergence, and adjusting the vaporizer to prevent gases from venting to the atmosphere.

Compared with those of the volatile anesthetics, the GHG effects of propofol are minimal. Propofol is, however, not a benign drug in reference to its environmental effects. Mankes[16] specifically looked at propofol wastage and its environmental impacts. He found that propofol does not degrade in nature, accumulates in body fat, and is ultimately toxic to aquatic life. He recommended that propofol wastage—and in turn environmental impact—could be reduced by only stocking 20-mL vials.

DISCUSSION

Environmental air pollution and climate change pose threats to health, food and water insecurity, increases in infectious disease, extreme weather, and population migration.[17] Health care providers should be cognizant of the environmental impact of the care they provide. Anesthesia providers must own the entirety of their practice, realizing that the impact does not end when the patient leaves the operating room. Aside from the fact that inhaled anesthetics have a negative effect on the ozone layer and global warming, if we know that inhaled anesthetics have enough of a negative health impact that we must restrict exposure to these gases in the operating room, why do we simply vent them into our surrounding environment? Given the findings of this literature review, it appears that all volatile anesthetics contribute, to some degree, to global warming. WAG recycling systems have the potential to decrease these effects.

Recycling has become an everyday part of our lives outside the operating room. With the development of these new technologies, recycling can now take place in the operating room as well. As such, we should advocate for the use of these technologies in everyday practice. Recycling of WAG holds the potential to eliminate the direct impact these agents have on global warming and the ozone layer as well as the potential to reduce the impact of their manufacture and transportation.[12]

Technologies for the collection and recycling of anesthetic waste gases include the Dynamic Gas Scavenging System developed by Anesthetic Gas Reclamation and implemented and tested with the Vanderbilt University Medical Center.[18] With this system, 99% of anesthetic gases are collected and reused. Because the vacuum only runs 10% of the time, the system also produces energy cost savings. The Deltasorb canister developed by Blue-Zone Technologies filters self-sterilizing anesthetics that can then be sold back to pharmaceutical companies at costs less than the costs of producing the original drug.[18] Challenges to the reuse of WAG include transmission of infectious disease, degradation of the quality of the drugs, costs, and existing market pressures from anesthetic gas manufacturers.[13]

Until these systems can be implemented on a widespread basis, anesthesia providers must be vigilant in reducing the environmental impact and costs of anesthesia. Employing techniques to limit hazards include low-flow anesthetics, choice of anesthetic agents, and proper maintenance of equipment. High FGFs are only necessary when rapid changes in anesthetic depth are necessary (eg, induction and emergence). Maintenance, often the longest phase of anesthesia, is the ideal time to use low FGFs and to minimize anesthetic waste gases. Using an estimated oxygen consumption of 5 mL/kg/min for a 70-kg patient, only 350 (mL/min) oxygen, plus additional oxygen to compensate for sampling and circuit leaks,[8] is required to deliver a volatile agent and maintain patient oxygenation. To safely implement low FGFs, close monitoring of inspired and expired oxygen concentrations is essential. Decreasing inspired concentrations of oxygen indicates underestimation of oxygen metabolism and flows should be increased accordingly.[8]

This review was limited by the relatively small body of literature on this topic. To further these findings, more research and development is required. While there is more literature pertaining to the science of global warming and climate change, this remains a highly debated and politicized topic. Perhaps a focus on the financial benefit of WAG recycling would be the most effective avenue for gaining support for these technologies. One alternative to the use of volatile anesthetics is the use of total intravenous anesthesia. Propofol and other intravenous anesthetics are not without environmental impact.

SUMMARY

In 2009, Costello et al declared, "Climate change is the biggest global health threat of the 21st century."[19] Given the environmental impacts of the inhaled anesthetics and the development of new technologies for WAG reclamation, this technology should be widely implemented when clinically available. Given the interplay between environment and health, changes in practice that reduce or eliminate WAG are worthy of consideration by health care providers. The potential cost savings associated with reclaimed reusable anesthetic should be investigated further.

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